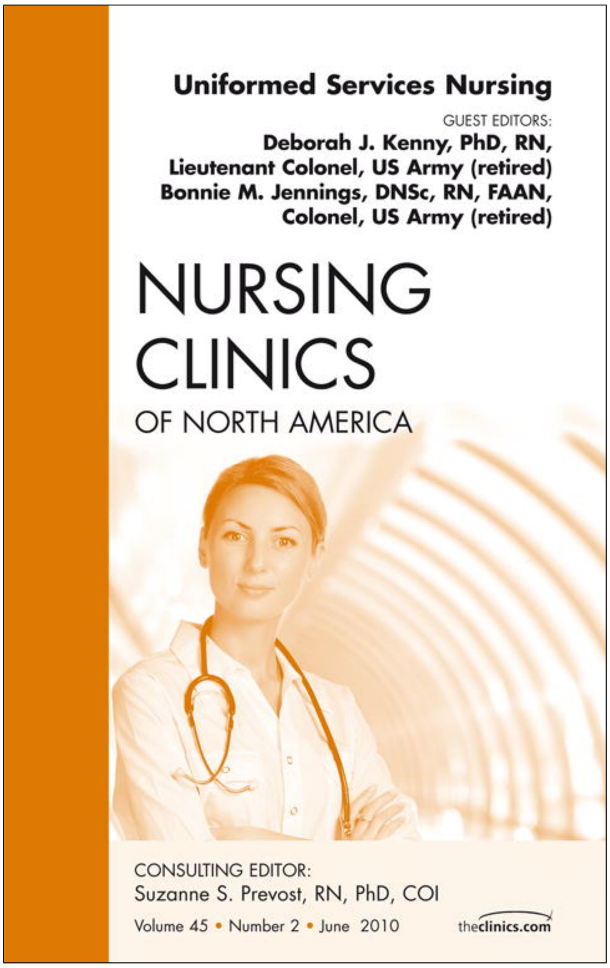
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Iron Deficiency in Women and Its Potential Impact on Military Effectiveness

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• Military • Iron deficiency • Women's health • Iron screening
• Risk factors • Iron deficiency anemia

In 1993, the Presidential Commission on the Assignment of Women in the Armed Forces rescinded the risk rule, which had prohibited women in the US military from serving in certain positions based on a substantial risk of capture.[1] Lifting this ban allows today's military women to serve in positions that historically had not been open to them, such as aviator, navigator, mechanical technician, infantry, gun crew, just to name a few of the historically all-male military positions.[2] Today, more women are choosing to join the military and are serving their nation with a greater choice of military occupations.

Women make up 14% of the US military population, with the US Air Force having the highest proportion of women: 19%.[3] In Iraq and Afghanistan combined, 10% of those serving in the military are women.[4] The increased number of women has required the military medical system to assess the health care services provided in both the continental United States and in rugged settings abroad, whether in deployed or humanitarian settings. These services must be delivered in the context of differences by gender in health and illness so as to maintain a fit and ready force. Fortunately, research that examines and sheds insight into the salient differences in health care needs between men and women is burgeoning. Some health care conditions, such as iron deficiency (ID), are more prevalent among women than among men. ID can reduce the oxygen-carrying capacity of blood, in turn impairing optimal physical and cognitive functioning. The high prevalence of ID in military women parallels the high prevalence of this problem in women athletes, and this must be

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considered a condition that warrants regular screening to help ensure the optimal performance of military women. ID is defined by the Centers for Disease Control and Prevention (CDC) as "an abnormal value for at least two of the following three indicators: serum ferritin, transferrin saturation, [or] free erythrocyte protoporphyrin."[5] Those with ID who also have a low hemoglobin value (<12 g/dL) are considered to have ID anemia (IDA).[5]

It is widely known that women are diagnosed with IDA at a far higher rate than are men,[6] and ID continues to be identified as a health concern primarily for women. For those in the military, having ID can be detrimental to completing their mission because of its potential to restrict physical and cognitive functioning.[6,7] However, the true prevalence of ID in women serving in support of Operation Iraqi Freedom/Operation Enduring Freedom (OIF/OEF) has not been published.[8]

Women who voluntarily join the US Armed Forces (Army, Navy, Air Force, Marines) represent all racial, ethnic, and socioeconomic backgrounds, and more than half are aged 18 to 24 years.[9] Unfortunately, women of childbearing age, a category that includes the great majority of military women, are at the greatest risk for ID.[6] This is important, because undiagnosed and untreated ID can become IDA, which could affect the military mission negatively by making women unable to perform at optimal levels.

To date, the iron status of military women has not been explored systematically on a population basis. Few data exist to determine the relationship between blood mineral levels and performance in military women, but this relationship has been studied in similar nonmilitary populations.[8] The purposes of this article are to present relevant research and clinical knowledge regarding the sequelae of ID, to propose that additional clinical resources be allocated to routinely screen for this condition, and to ask for continued research on the effectiveness of screening and clinical interventions, especially during physically strenuous missions.

THE DEFINING CHARACTERISTICS OF ID

Patients with ID can vary from being completely asymptomatic to having symptoms similar to anemia, such as weakness, headache, irritability, varying degrees of fatigue, and exercise intolerance.[10] Women who undergo intense military physical and mental training, however, are likely to dismiss these vague symptoms as a result of exhaustion from their training. A physical assessment for people with chronic ID can include evaluating the patient for the symptoms described above and for glossitis, angular stomatitis, koilonychia (spoon nails), blue sclera, esophageal webbing (Plummer-Vinson syndrome), and anemia. Abnormal food cravings, known as pica, also can be exhibited by people with ID, who may resort to eating dirt (geophagia) and ice (pagophagia) without an apparent biologic reason for these cravings.[11]

THE PHYSIOLOGY OF IRON ABSORPTION

In people, iron is obtained in two ways: absorption from foods in the gastrointestinal (GI) tract and recovery from senescent and damaged erythrocytes.[12] Iron obtained from the GI tract is absorbed in the first section of the duodenum, a highly acidic environment that is necessary for the membrane iron transporters.[12] There are two types of dietary iron: heme and nonheme. Heme iron already has been incorporated into the heme molecules—hemoglobin and myoglobin—both of which are absorbed well in the body. Most of the Western population's consumption of iron in food is nonheme iron found in plant foods and fortified food products. Indeed, only about 10% of the iron in the typical Western diet is heme iron, which is derived from meat, poultry, and fish.[13]

The bioavailability of nonheme iron is variable and depends on the current diet and the amount of iron already present in the body.

Regardless of the type of iron consumed, the minimum daily dietary requirement for this mineral among women aged 19 to 30 years is 18 mg/d.[5] Nonheme iron is less readily absorbed, and its absorption is strongly influenced by the other foods ingested at the same meal.[6] Foods or beverages high in bran, dietary fiber, calcium, tannins (in tea and coffee), oxalates, phylates, and polyphenols (in certain plant-based foods) can interfere with absorption. Foods rich in ascorbic acid (vitamin C), such as citrus fruit, broccoli, mango, pineapple, and guava, in contrast, will facilitate the absorption of iron.[6] Additionally, foods rich in heme iron promote the absorption of nonheme iron.

Iron that is not needed immediately is stored in ferritin molecules, primarily in the liver, bone marrow, and spleen.[13] A single ferritin molecule holds up to 4500 atoms of iron.[12] In a healthy person, most of the iron in the body is conserved and reused. Although iron losses are usually minimal, they do occur through the GI tract, skin, urine, and with menstruation.[13]

PATHOPHYSIOLOGY OF ID

In people, a decline in iron status occurs in stages and is usually gradual. If not treated, it can progress from iron depletion, to iron-deficient erythropoiesis, and finally to IDA.[6] The decline develops when the iron demand is not met by available iron, resulting in insufficient iron for the synthesis of hemoglobin.[14] The iron and hemoglobin deficiency eventually will produce iron-deficient red blood cells.[10]

A normal laboratory serum ferritin level ranges from 40 to 160 μg/L for females; iron depletion is reflected by a serum ferritin between 12 and 20 μg/L. In ID, the serum ferritin is less than 10 μg/L up to 12 μg/L, a level at which the stores are considered to be exhausted.[13,15] ID is diagnosed when the depletion of iron stores begins to impair the synthesis of hemoglobin.[13] If the negative iron balance is not corrected, the final stage of ID is IDA, which is known as one of the microcytic anemias, in which the red blood cells look pale and small.[13]

DIAGNOSTIC EVALUATION

Asking people to recall their diet is not an effective method of screening for ID and cannot substitute for further testing, if warranted.[13] The gold standard for identifying ID or IDA is a direct test bone marrow biopsy with Prussian blue staining, but this test is not practical for screening.[13] The complete blood count (which includes the hematocrit, hemoglobin concentration, mean corpuscle volume, and red blood cell distribution width) is the basic measurement for determining the late stages of ID or IDA.[13] Serum biochemical markers, as will be described, such as serum ferritin, serum iron, total iron-binding capacity, transferrin saturation, serum transferrin receptor, and zinc protoporphyrin/heme, are helpful in identifying ID before the onset of IDA. Normal and abnormal values are depicted in **Table 1**. Serum biochemical markers include:

Serum ferritin is an early marker of ID and is highly specific for this condition. Serum ferritin is the storage compound for iron, and low levels correlate with a diagnosis of ID.[16] However, other conditions can alter the serum ferritin levels, such as inflammation, chronic infection, and other diseases.

Serum iron concentration, which can be measured directly, generally decreases as iron stores are depleted. The ideal serum iron concentration is greater than 115 μg/dL. The serum iron concentration also can be influenced by extraneous factors such as iron absorption from meals, infection, inflammation, and diurnal variation.

Table 1
Laboratory analysis for identifying iron deficiency and iron deficiency anemia

Laboratory Test	Normal Range	Iron Deficiency	Iron Deficiency Anemia
Hematocrit	38–50%	38–50%	<38%
Hemoglobin	12–16 g/dL	12–16 g/dL	<12 g/dL
Red blood cell volume distribution width (RDW)	≤15%	>15%	>15%
Mean corpuscular volume (MCV)	80–100 fL	Normal range or <80 fL	<80 fL
Total iron binding capacity (TIBC)	330 ± 30 mcg/dL	360–410 mcg/dL	≥410 mcg/dL
Ferritin	100 ± 60 ng/mL	≤20 ng/mL	<12 ng/mL
Iron	115 ± 50 μg/dL	<115 μg/dL	<40 μg/dL
Soluble transferrin receptor	<35 mg/dL	≥35 mg/dL	≥35 mg/dL
Transferrin saturation	35 ± 15%	<20%	<10%
Zinc protoporphyrin/Heme	<40 μmol/mol	≥40 μmol/mol	≥70 μmol/mol

Total iron-binding capacity (TIBC) measures the availability of iron-binding sites. Extracellular iron is transported in the body bound to transferrin, a specific carrier protein. Therefore, TIBC indirectly measures transferrin levels, which increase as the serum iron concentration decreases. This test has lower values in the presence of conditions such as malnutrition, inflammation, chronic infection, and cancer.

Transferrin saturation (Tfsat), which indicates the proportion of occupied iron-binding sites, reflects iron transport rather than storage. Tfsat is calculated by dividing the serum iron concentration by TIBC. A low Tfsat implies low levels of serum iron relative to the number of available iron-binding sites, which suggests low iron stores. Tfsat decreases during the iron-deficient stage and is less sensitive to changes in iron stores than serum ferritin.

Serum transferrin receptor (TfR) is present on the reticulocyte membrane. With iron deficiency in the tissues, there is a proportional increase in the number of transferrin receptors. TfR is useful as an early marker of ID, and it is also helpful in differentiating between IDA and anemia of chronic disease (this test is not readily available in the military health care system).

Zinc protoporphyrin (ZPP) is formed when zinc is incorporated into protoporphyrin in place of iron during the final step of heme biosynthesis. Normally, the reaction with iron predominates, but when iron is in short supply, the production of ZPP increases, and the ZPP/heme ratio (reported as ZPP) becomes elevated. ZPP is elevated in the setting of lead poisoning and chronic disease. A newer hematologic test, reticulocyte hemoglobin content, may help diagnose ID before anemia is present.[13]

PREVALENCE OF ID

ID is a common diagnosis worldwide.[16] Interestingly, it is the only nutrient deficiency of significant prevalence in the developed nations.[6] In the United States, the Healthy People 2010 report called for a reduction in ID in children and pregnant women. In order to collect data for the prevalence of ID in the US population, the CDC uses the National Health and Nutrition Examination Survey (NHANES), which relies on a nationally

representative sample of the US civilian noninstitutionalized population.[17] In the third NHANES (NHANES III, 1988 to 1994), researchers found that 11% of female adolescents (ages 16 to 19 years) but less than 1% of male adolescents had diagnostic symptoms of ID.[18] In addition, 3% of female adolescents had diagnostic symptoms of IDA. The next age group of women, ages 20 to 49, had an incidence of ID equal to that of the adolescent girls, 11%, but their incidence of IDA was 5%. Among military women, one study found a 13.4% prevalence of ID at initial entry into military service, but following military basic training for 9 weeks, the prevalence increased to 32.8%.[19] Women in the US military who are aged 18 to 24 years are at equal or greater risk for developing ID/IDA based on the risk factors summarized in the next section.[9]

RISK FACTORS FOR ID IN WOMEN

Women at the greatest risk for ID are those who suffer with a chronic illness, experience heavy menstrual blood loss (>80 mL/month), or who are underweight or malnourished. This at-risk population should be screened.[10] Additionally, donating blood puts women at risk for ID.[15] Because requirements for military recruitment and retention limit and often restrict military service for women with chronic disorders, chronic illness and digestive illness will not be discussed as a cause of ID in this article. Also, for this article, it is assumed that military women are typically at their adult height, and thus growth spurts will not be covered as a contributor to ID in this population. In brief, the topics covered in this section will be limited to factors that render the military women in general at risk for ID.

Loss of Blood Through Menstruation

Women of childbearing age are at increased risk of ID because of monthly blood loss from menstruation. In a cross-sectional study of 335 premenopausal women in New Zealand, researchers found that women with a longer duration of menstrual flow (5.2 days) were more likely to be diagnostic of ID than were women with a shorter duration (4.9 days).[15] Proportionately, more women with a shorter duration of menstruation took oral contraceptives than the group with longer duration. In this study, diagnosis of ID was more common among women who did not use oral contraceptives (72.4%).

Experts recommend that oral contraceptives be used to treat ID,[20] but there are several other hormonal contraceptives that are an ideal reversible contraceptive method to decrease menstrual blood loss, particularly for women who wish to preserve their fertility. In addition to all combined oral contraceptive pills, examples include the levonorgestrel intrauterine system (Mirena; Bayer Health Care Pharmaceuticals, Wayne, NJ, USA), the etonogestrel contraceptive implant (Implanon; Schering-Plough Corporation, Kenilworth, NJ, USA), and injection with medroxyprogesterone acetate (Depo Provera; Pfizer, New York, NY, USA). With the exception of certain oral contraceptives, all the methods listed here are available to military women on request.

Race/Ethnicity

Researchers reporting results from NHANES III (1988 to 1994) and NHANES for 1999 to 2000 found that the prevalence of ID in these two studies was greater in non-Hispanic African American (15% to 19%) and Mexican American (19% to 22%) females than in non-Hispanic white (8% to 10%) females.[5] IDA is also more prevalent among women of color. For example, in a national survey, researchers reported much higher IDA rates for non-Hispanic African American (12.2%) and Mexican American (7.6%) females than for non-Hispanic white (2.6%) females.[21]

In a study of 1216 US Army women, differences in ID between racial/ethnic groups were consistent with other national studies. In this study, upon entry into military service, African American women were more likely to be diagnosed with ID (16.7%) than were white (8.9%) or Hispanic (7.1%) women.[19] At the conclusion of 9 weeks of physically and mentally intense basic military training, however, the rates of ID among all three racial/ethnic groups had increased. The greatest increase in prevalence was in the Hispanic women (a rise of 43.8%), followed by African American (up 32.5%), and white (up 24.8%) women.[19] Even though all women are offered the same meals in the military cafeterias during training, this does not mean that consumption is equal. The lack of cultural or personal food choice preferences in the cafeteria setting may be a possible contributor to women choosing not to eat the food that is offered.

Weight

In a New Zealand study of 335 women, researchers found that women with a body mass index (BMI, the weight in kilograms divided by height in meters squared) of less than 20 were more than twice as likely to be diagnosed with ID as women with normal BMI.[15] In a US study, the prevalence of ID among new military recruits who were underweight (BMI $\leq$19) was 18.3%.[22] Women should be encouraged to maintain a healthy weight and consume calories according to their activity level.

Military members of both genders serving in deployed locations are at risk for substantial and unintentional weight loss due to the lack of access to their personal food preferences, increased physical and emotional stress, and increased demands on their physical energy. Anecdotally, members of the military have verified weight loss associated with a recent deployment; this weight loss can come with a price of insufficiencies in micronutrients.[8] In addition, experts reported that under field conditions, with either field rations or with fresh foods, military members' serum ferritin decreased.[23] It is unclear why ferritin levels would decrease in the field environment, but this finding suggests an elevated incidence of ID, although to the authors' knowledge, ID has never been measured or reported among military members in this environment.

Dietary Choices

For whatever reason, many women do not consume the recommended daily reference intakes (DRI) of 18 mg/d of iron as established by the Food and Nutrition Board of the Institute of Medicine (National Academy of Sciences).[24] Also at risk for ID are those women who make restrictive diet choices, such as vegetarians.[10] There are no statistics on the number of military women who eliminate certain foods from their diets, but given the worldwide mobility of today's military, women who are deployed may be offered limited food choices based on what is immediately available.

Variety in food intake usually depends on how long military personnel are in a deployed location and the resources available for food preparation. The serving of food can vary from a buffet-style cafeteria with many options to a "meal ready to eat" (MRE) consisting of dried and canned foods in a pouch preserved for long shelf life and devoid of many natural nutrients found in fresh food. The usual food choice in the early stages of a humanitarian or contingency operation is MREs. The contents of these meal pouches are based on the dietary needs of the average male military member, however. Each MRE contains 7 to 9 mg of iron and will average around 1300 calories. Women in equal field conditions with similar activity levels do not need as high a caloric intake as men, and many will limit the number of meals they consume and, therefore, reduce their intake of iron below the DRI.

In 2006, the Institute of Medicine committee[8] reported a paucity of appropriately designed studies to give an accurate estimation of needs for iron in deployed locations, but it surmised that during deployment military members are highly active and experience increased iron loss through sweat and thus need more dietary intake of iron.[8] It is the recommendation of the Institute of Medicine[8] that women in military training or who are deployed receive 24 mg/d of iron due to the increased losses.[8] Interestingly, the Nutritional Standards for Operational Rations set the minimum daily requirement lower at 15 mg/d, 3 mg below the DRI.[8]

Donation of Blood

At times, members of the military may be called upon to donate blood for banking, or sometimes they simply take it upon themselves to give blood. After the national attack on Sept. 11, 2001, hospital employees and military members stationed at military treatment centers set up donation centers, and military personnel came in large groups to donate blood without prompting. This description of blood donation in times of crisis is not isolated to certain military bases, as such selfless acts have taken place across many military installations worldwide. Such altruism, however, can place women who may already have ID at further risk. Prior to donation, the blood banks check the hematocrit of their potential donors, and if is above 36% the candidate is approved for donation. The hematocrit, however, is a poor marker of hematological health overall. Moreover, in the New Zealand study, women who donated blood within the previous 4 months were seven times as likely to have decreased iron stores as women who had not donated, and they were more likely to be diagnosed with ID.[15] With this reported increased risk of ID following blood donation, it is interesting to note that in its 2006 report, "Mineral Requirements of Military Personnel," the Institute of Medicine did not describe the effects of blood donation on military personnel and did not recommend tighter surveillance of military members who donate blood.[8] Regardless, because of the substantial likelihood of developing ID from recent blood donation, military medical treatment facilities should screen for ID in women who have recently donated, and these women should be monitored by military medical professionals.

Physical Training

Because of the physical fitness requirements for the military, an overview of the risk factors for ID in athletes is relevant to this discussion. These risk factors include poor iron intake and restrictions on diet, increased erythropoiesis/turnover of red blood cells, GI blood loss, iron losses in sweat, foot-strike hemolysis, and thermohemolysis.[25,26] Athletes participating in impact sports have a greater prevalence of ID than those in nonimpact sports.[27,28] In one study, researchers reported that 36% of aerobically fit females had ID as compared with only 6% of their male counterparts.[29] Runners appear to have the highest incidence of ID, which is due to hemolysis from striking the foot.[26] Physical fitness assessments in the military rely heavily on the member's running time, but anaerobic measurements are taken also.

In a small study of Israeli female military recruits (average age 18 years), researchers reported an alarming rate of iron depletion (the serum ferritin level was <20 μg/L for 77% of women tested).[30] Furthermore, 10% of those women were found to have ID (ferritin level <12 μg/L). Elsewhere, in a double-blind, placebo-controlled study under way at the US Air Force Academy (USAFA) in Colorado Springs, Colo., researchers found that 14% of the female freshman cadets arrived at USAFA with a serum ferritin level below 12 mg/dL, while nearly 43% additional freshman women had a value below 20 mg/dL, suggesting that over half of these female recruits entered the military with

either outright ID or in an iron status that placed them at risk for ID.[31] These female volunteers were randomly assigned to cohorts receiving either a daily pill containing 100 mg ferrous sulfate or a daily placebo, with instructions to take one pill every day. Following 6 weeks of basic military training at moderate altitude (the USAFA is approximately 7000 feet above sea level), over 55% of the subjects receiving the placebo had a serum ferritin value below 20 mg/dL, and nearly half had ID or IDA. None of the subjects receiving the daily iron supplement had IDA, however, although three could still be classified as iron depleted based on serum ferritin values above 12 but below 20 mg/dL. Although both groups displayed significant gains in total hemoglobin mass and blood volume, which would be expected when training at altitude, no significant differences in blood measures were evident within the first 10 weeks at altitude between the iron and placebo cohorts.[31] Statistically significant differences in blood volume and total hemoglobin mass became apparent as the year progressed, however, with the placebo group having lower blood values and worse exercise performance. Additionally, female subjects not receiving iron supplementation required a significantly longer time to fully adapt to USAFA's altitude, based on numerous measured blood parameters that included total hemoglobin mass, which was measured using the optimized CO (carbon monoxide) rebreathing protocol.[31]

In another study, this one of women in the US Army, researchers found that the prevalence of ID had jumped from 13.4% at the beginning of training to 32.8% at the end.[19] They attributed this dramatic increase to physical activity and a possible decrease in dietary iron. Earlier, Beard and Tobin observed that the prevalence of ID was likely to be higher in athletic women than in sedentary women.[11] The causes for the increased prevalence are speculative but are likely related to dietary choices and to increased turnover rates of both red cell and whole-body iron.[11] These speculations on the increased prevalence of ID among athletic women can be applied to military women in training because of the intense physical exercise necessary at that stage of military service.

EFFECTS OF ID ON PHYSICAL PERFORMANCE

As noted earlier, physical training can cause military women to develop ID, but the effects of ID on fitness also must be considered. Those who have ID can experience a substantial reduction in their capacity to exercise, a fact that creates a vicious cycle until the person is treated and the negative iron status is eliminated. ID alters exercise performance because of the decrease in oxygen transport to exercising muscle.[11]

Women working in certain military positions are required to perform at a physical fitness level that is comparable to that of men because of the demands of the position. Some military positions require fitness standards that are "normed" to the job (in these cases, men and women are expected to perform equally), such as a US Air Force aviator.[32] ID interferes with women's ability to perform at that capacity. In the Institute of Medicine's 2006 report "Mineral Requirements of Military Personnel," researchers reported that having IDA limits physical endurance.[8] The reduced levels of serum iron and the lower capacity of iron-dependent muscles contribute to lower endurance and energy inefficiency.[8] The recommendation by the Institute of Medicine regarding the impact of ID on performance was that military personnel be screened for iron status.[8]

EFFECTS OF ID ON EMOTIONAL/COGNITIVE PERFORMANCE

The connection between ID and impaired emotional status and reduced cognitive performance is convincing and deserves further investigation. In an Iranian study, researchers reported that female medical students diagnosed with depression had a mean serum ferritin level of 27.0 plus or minus 11.3 μg/L, well below the mean value

of those who were not depressed: 38.4 plus or minus 17.1 μg/L (p<.05). The women in this study with ID were diagnosed with depression at a rate twice that of women without ID.[33] This connection between ID and depression is concerning and is relevant for military personnel. More recently, researchers reported that mental disorders were more common among women (9.0%) than men (5.7%) in Operation Iraqi Freedom.[34] Finally, McClung and colleagues[35] reported recently that iron supplementation for women with ID improved their mood and physical performance during military training in comparison with a group receiving placebo.

Reduced intellectual performance is a well-known and serious consequence of prolonged ID in children.[6] This consequence indicates that we should be concerned about young women with prolonged ID. Experts have reported overwhelming evidence that iron supplements given to women with ID improved both their learning and memory.[13,14]

THE EFFECT OF ID ON ADJUSTMENT TO ALTITUDE

People who travel to high altitudes (>9000 feet above sea level) generally experience weakness and anorexia during their initial adjustment to the altitude as well as other problems.[36] Weight loss is common with chronic exposure to high altitude until people become adjusted, and this loss of weight may be associated with an inadequate diet of iron-rich foods. In a retrospective study of male and female USAFA cadets, Brothers and colleagues[37] found that cadets who came to this moderate-altitude military academy from a location that was less than 900 feet above sea level demonstrated significantly lower aerobic and anaerobic physical fitness scores for 2 years when they were compared with those who came from locations with a moderate altitude (4500 to 9000 feet). This prolonged adjustment to altitude, when coupled with the presence of ID, is a concern because of ID's known effect on endurance capacity and energy levels.[8] In addition, Brothers and colleagues found that roughly one third of cadets coming from sea level (both male and female) experienced a drop in serum ferritin values to below 20 mg/dL. This drop in serum ferritin suggested that iron intake, although exceeding the DRI values, was insufficient for the erythropoietic demands of acclimatization to altitude. Physiologic adjustment to acclimatization, which produces a ferritin deficit, combined with the demanding military training environment, may have been a key reason for the protracted period of acclimatization and poorer athletic performance for up to 2 years. In the deployed setting, this combination of acclimatization to altitude and the presence of ID can be a hazardous combination, putting the health of the women and their military mission at risk.

A follow-up prospective study that included both male and female cadets (although only the data for males have been published thus far) from either sea level or moderate altitude produced the same results as summarized here, with former sea-level residents displaying significantly worse exercise performance for their first year at altitude.[38,39]

ID AND HEMORRHAGE

In any military conflict or training exercise, there is a risk of serious harm from hemorrhagic injuries. Clearly, women in such a setting who suffer from depleted or deficient iron stores are at a disadvantage compared with those who are not iron deficient. Although conceptually one can understand the risk of decreased oxygen-carrying capacity to vital organs that results from ID combined with hemorrhagic injury, a MedLine keyword search by the authors using the search terms of "iron deficiency," "iron deficiency anemia," "injury," and "hemorrhage" found no cross-matched articles

from the year 1950 to the present that were relevant to the topic of hemorrhage in the setting of ID. However, researchers conducting a retrospective study on occult bleeding following trauma found that lower hemoglobin levels ($\leq$10 g/dL) in the early stages of hemorrhage were associated with an increased heart rate, decreased blood pressure, decreased pH, worsened base deficit, and increased requirements for transfusion.[40] Therefore, one could logically argue that the physiologic effects of hemorrhage might be exacerbated by the presence of ID. Certainly, decreased organ perfusion coupled with lower oxygen-carrying capacity could have serious consequences.

RECOMMENDATIONS FOR SCREENING

Whether screening for ID is cost-effective is a controversial issue among health care experts. Currently, there is no recommendation to screen for ID in women who are involved in intense military training or deployment. In addition, in a review of the literature, experts reported there was no compelling evidence from a preventive point of view to screen for iron in athletes.[41] Although recent research demonstrated an unexplained decline in the prevalence of IDA among US women, the prevalence of ID was unchanged; women with ID would still be at risk for worsening of that condition and possible IDA if the ID was uncorrected.[21] Researchers from two different studies attributed ID in female athletes and female military recruits to menstruation, inadequate dietary iron intake, GI bleeding, foot-strike hemolysis, sweat losses, and malabsorption of iron.[30,42] According to the US Preventive Services Task Force, there is at least fair evidence to support the screening of pregnant women for IDA to improve their health outcomes.[43] There is, however, no national standard to screen women for ID per se, and, therefore, there is not enough evidence to support the need for population screening. Experts in athletics, however, recommend the screening of elite athletes. In summary, the evidence presented here clearly indicates the need to screen for ID among military women, especially those who are in demanding physical situations or who are deployed for long periods of time or to higher altitudes.

NURSING CONSIDERATIONS

Nursing interventions for ID should be focused on educating the patient about the need to eat iron-rich foods. In addition, education should inform women about the signs and symptoms of ID. Nursing interventions also should include education on improving the uptake of iron while minimizing its loss. The fact that foods high in vitamin C interact with foods containing moderate-to-high levels of iron to increase uptake of the iron should be addressed.[15] Another key intervention is discussing options for minimizing menstrual blood loss among women for whom this is a problem.[15] Although information on suppressing menstruation is focused on the benefits of not having to manage menstruation while deployed, nurses should include the improvement of iron status as a second benefit of menstrual suppression.[20] It should be noted that despite the proactive campaign to educate military women about the beneficial effects of suppressing menstruation through hormonal contraceptives, military women continue to report their concern about the safety of this practice.[44] Nurses should reinforce the fact that menstrual suppression is a safe practice in order to dispel any myths or misconceptions.

Iron supplements provide the greatest improvement in iron status for women aged 19 to 50 years, of whom a reported 23% prophylactically supplement with iron. Groups at the greatest risk for ID (ie, low-income and minority women), however, are often least likely to consume iron supplements, and the dose of iron in multivitamins that contain this element is not sufficient for iron replacement in women with

ID.[16,45] Women who are prescribed iron supplements, typically an iron salt such as ferrous sulfate, should be warned of the typical GI side effects (such as constipation, dark or green stools, diarrhea, nausea, upset stomach, vomiting, and flatulence) to promote compliance with this therapy.[16] Teaching women about keeping their stools soft by using stool softeners and increasing fiber and water is an important intervention. Nurses need to ensure that follow-up testing of iron status is done every 3 to 6 months while women are on iron supplements.

Nursing considerations include educating health care colleagues about the generalized and vague symptoms that can be reported by athletic, military women that can be mistaken for the effects of intense physical training. This concern is especially important if there is a history of ID or, more importantly, IDA. Nurses should advocate for women who consistently score poorly on the physical fitness tests and consider screening them for the symptoms of ID and testing their iron status.

RESEARCH NEEDS

Given the high number of women who are diagnosed with conditions that could be the result of ID, additional research is needed in situations that simulate the deployed environment. Although population statistics are available along with a limited number of studies from military samples to demonstrate the prevalence of ID in women, the authors believe ID is underdiagnosed. ID is most likely dismissed because the usual tests by health care providers for its symptoms, such as fatigue, will not typically include a panel of the tests for iron listed previously. The amount of time needed to obtain results for an iron study panel can vary from laboratory to laboratory, but it is often quite substantial. Thus, the research community should be challenged to develop rapid and cost-effective screening methods for meeting the needs of the female military population.

Additional intervention studies are needed to test the appropriate intervention methods for women with ID in the deployed setting. Although the Institute of Medicine speculated in 2006 about the correct DRI for physically active women, there are unique risk factors for military women in a deployed setting that can place these women at greater risk for ID.[8] Therefore, research studies are needed to find the appropriate iron intake for women who are deployed. Some studies have examined iron supplements, and others have looked at improved iron intake through the diet. However, both interventional methods must be tailored to the deployed setting, which can vary in terms of the availability of supplements and foods.

Although the Institute of Medicine committee reported a decreased need for iron requirements for women on oral contraceptives, the committee did not outline the iron needs of women on a regimen of menstrual suppression.[8] This information would be helpful to inform women about the benefits of menstrual suppression that exist in addition to the obvious benefits of no menses and the decreased symptoms related to premenstrual changes.

SUMMARY

With the military population consisting of more women than ever before in US history, it is incumbent on military and health care leaders to explore the effect of ID on women, who are more at risk than men. Although the prevalence of ID in the deployed setting has not been published, based on populations similar to military women in training as well as studies of such women (female military trainees) one can speculate that the prevalence of ID in the deployed setting is between 11% and 43.8%. This high prevalence can be detrimental to the military mission, as the usual symptoms of ID are

weakness, headache, irritability, fatigue, and exercise intolerance. The symptoms of ID can be exacerbated at deployed locations with moderate or high altitudes, such as northern Iraq and Afghanistan. Furthermore, the degree to which ID might exaggerate injury from hemorrhagic trauma is unknown, but it is speculated that women with ID who suffer such trauma might take longer to reach a stable state. Nursing interventions are paramount for improving the health of military women and must be applied when caring for this unique at-risk population.

It is the authors' recommendation that screenings begin early and occur often for military women in their childbearing years. Military women should be screened for ID to implement interventions to improve their physical fitness scores, cognitive scores, and overall well-being. The likelihood that women will be deployed to a foreign land for war or humanitarian missions is high. Waiting until women are deployed to screen is too late, because the availability of biochemical tests, such as serum ferritin, serum iron, and TIBC may be limited in austere or first-wave deployments. Therefore, it is incumbent on the military health care system to screen women for ID on an annual basis and before deployments, and provide appropriate treatment in order to put women in the best position to perform optimally to complete the military mission.

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